DEUTERIUM AND COMETARY RESERVOIRS. J. Horner[1], O. Mousis[2] and F. Hersant[3], [1]Physikalisches Institut, Universitaet Bern Sidlerstrasse 5, CH-3012 Bern, Switzerland (Jonathan.Horner@phim.unibe.ch); [2]Observatoire de Besançon, CNRS-UMR 6091, 41 bis, avenue de l'Observatoire, BP 1615 Besançon, France (Olivier.Mousis@obs-besancon.fr); [3]LESIA, CNRS-FRE 2461, Observatoire de Paris, 5 place Jules Janssen, F-92195 Meudon, France (Franck.Hersant@obspm.fr).

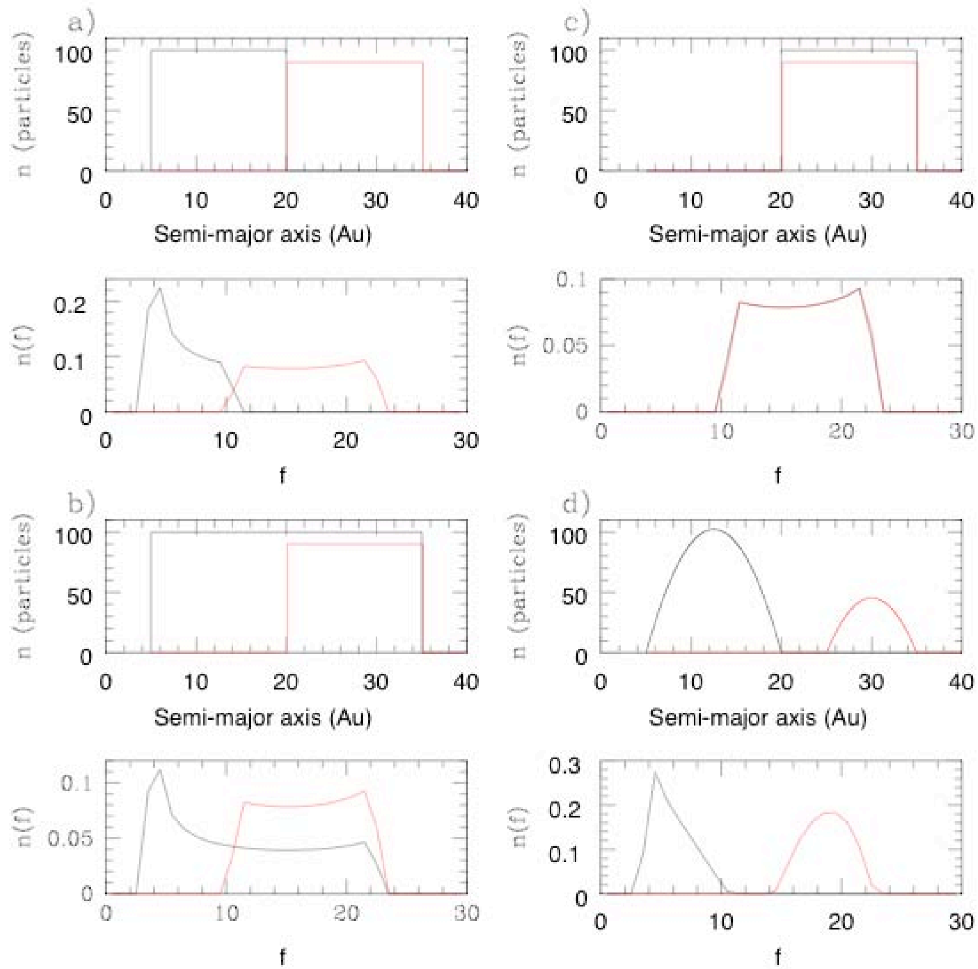
Introduction: One piece of evidence which may allow us to differentiate between different models of planet formation relates to comets. These icy bodies are likely to retain the isotopic composition they acquired when they formed [1]. As such, it may be possible to determine, from their observed properties, their formation region. Within our Solar system, there are two main reservoirs for these cometary bodies - the Edgeworth-Kuiper belt/Scattered disk and the Oort cloud. It is quite possible that the comets which make up these reservoirs formed in different regions within the planetary nebula, and therefore comets from these different regions may have different compositions. Using a deuterium-enrichment profile, which offers a relationship between the deuterium to hydrogen (henceforth D:H) ratio incorporated in the water within planetesimals and their formation location in the Solar nebula [1] [2] [3] [4], we examine the possible effect that formation in different regions could have on the values of this ratio observed in comets today. We illustrate how such a model, when combined with observations, can lead to conclusions on the regions in which different cometary populations were born.

Isotopic fractionation of deuterium: The enrichment factor, *f*, resulting from the exchange between HD and HDO is defined as the ratio of D:H in the considered deuterated species to that in molecular hydrogen. The evolution of *f* in the Solar nebula can be calculated using a diffusion equation [1] [2] [3] which takes into account the isotopic exchange between HDO and H_2 in the vapour phase, and turbulent diffusion throughout the Solar nebula. The diffusion equation is valid as long as H_2O does not condense. As soon as forming grains reach millimetre size, they begin to decouple from the gas, and continue to grow, forming planetesimals. Whatever the subsequent evolution of these bodies, their D:H ratio is that of the microscopic grains from which they formed. We consider the case where cometesimals formed in the Solar nebula were accreted only from icy grains formed locally. This means that the D:H ratio in the deuterated ices within comets is that which was present at the time and location at which they condensed.

Illustrating the effect of changing source populations: Given a relationship between the D-enrichment (*f*) with changing location in the Solar nebula [4], it is clear that measurement of this value in comets could be used to infer the location within the nebula at which the comet formed. In order to illustrate the changes that the differing views of comet formation will wreak on the observed distribution of *f* values in comets, and hence to show how observations of these values can aid us in the determination of these formation locations, we present four simple figures. In these diagrams, the *f* vs. *a* relationship, shown in figure 1, is combined with particularly simple assumed initial cometary populations, allowing the calculation of the resulting distribution of *f* values which would be observed. We illustrate the concept by showing two populations. One, which can be considered to be analogous to the objects which formed the Edgeworth-Kuiper belt, is always assumed to have formed between 20.1 and 35.1 Au, whilst the other, which may be taken to represent the objects which now make up the Oort cloud, is shown forming in different regions.

For each of the four diagrams, the upper panel shows the two initial populations used, while the lower shows the resulting *f* distribution (normalised so that the sum over all *f*-values equals one for each of the two populations shown). In the first diagram (plots a), the 'Oort cloud' population is taken as forming solely between 5 and 20 Au. In the resulting *f* distribution plot, two features are clearly seen. Firstly, there is a sharp spike in the 'Oort-cloud' section of the distribution at around *f* = 5. This is due to the plateau in the *f*-values in the inner region of the outer Solar system. The second feature is that the objects in the 'Edgeworth-Kuiper belt' region have a distinctly different *f* profile to those which went to form our 'Oort cloud'. It is clear from this that, if the Oort cloud and Edgeworth-Kuiper belt objects had formed in different locations, their observed *f* distributions would be measurably different. In the second diagram (b), the 'Oort cloud' population (now taken as forming between 5 and 35 Au) has a large amount of overlap with those particles which make up our 'Edgeworth-Kuiper belt'. However, despite this overlap, the two resulting *f* distributions are again noticeably different. Therefore, even if there was some degree of mixing between the two populations, differences would still be observed between them if they also encompassed different formation regions. The third diagram (c) shows the situation when the

'Oort cloud' and 'Edgeworth-Kuiper belt' populations formed in exactly the same region, with the same distribution. In this case, the resulting *f* distributions are identical, and the populations look the same in *f* space. The fourth, and final diagram (d) shows how studying the *f* distribution may also inform us about the initial distribution of objects within their formation region. In this diagram, a slightly more complicated distribution was used. In this plot, it can be seen that the shape of the initial distribution of comets has a radical effect on the shape of the resulting *f* distribution, and hence, that knowledge of the *f* distribution may be used to draw inferences on the initial population distributions within the regions of comet formation, beyond the simple location of those regions.



It is therefore clear that, given initial distributions for the comets which make up the different reservoirs within our Solar system, it is possible to calculate a theoretical *f* distribution for those populations. It is also clearly feasible to work the other way. Given enough observed *f* values for comets of different classes, one could work backwards to calculate where those classes were predominantly formed. Whilst the real initial distributions for the objects now in the Edgeworth-Kuiper belt and the Oort cloud are no doubt significantly more complicated than those used in illustrating the principle, it seems that future measurements of *f* values in a variety of comets could lead to a much greater understanding of the regions in which they formed.

References: [1] Drouart. et al. (1999) *Icarus*, 140, 129. [2] Mousis et al. (2000) *Icarus*, 159, 156. [3] Hersant et al. (2001) *ApJ*, 554, 391. [4] Mousis (2004) *A&A*, 414, 1165.

Figure 1: In each of the four diagrams, the upper shows the used population distributions, and the lower the resulting *f* distribution that would be observed. The red line shows our example 'Edgeworth-Kuiper' objects, and the black the 'Oort cloud' bodies.